An open-label trial of JAK 1/2 blockade in progressive IFIH1 -associated neuroinflammation

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CLINICAL/SCIENTIFIC NOTES

An open-label trial of JAK 1/2 blockade in progressive IFIH1-associated neuroinflammation

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IFIH1 gain-of-function causes a spectrum of neuroinflammatory phenotypes associated with enhanced type I interferon production and Janus kinase (JAK)/signal transducer and activator of transcription (STAT) pathway activation.[1,2] Patients most often present in infancy, variably exhibiting spasticity, dystonia, seizures, and acquired microcephaly. We report the use of ruxolitinib, a JAK 1/2 blocker, in the treatment of early-onset, progressive neurologic disease due to an *IFIH1* mutation.

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Case report

A 3-year-old boy born to unrelated white European parents developed normally until age 8 months, after which he experienced developmental regression with loss of trunk and head control so that he could no longer sit or hold objects. The following 8 months were characterized by sterile pyrexias, irritability, increasing spasticity, and exaggerated startle responses to sounds (video, links.lww.com/WNL/A107). At age 16 months, he was microcephalic, small, and centrally hypotonic with peripheral spasticity (table e-1, links.lww.com/WNL/A109). CSF was unremarkable except for elevated neopterin. Neuroimaging revealed mildly delayed myelination and no calcification. Genetic testing identified a de novo heterozygous p. Arg779Cys *IFIH1* substitution, as previously reported in a patient dying at age 3.5 years of a fulminant lupus-like syndrome on a background of neonatal-onset severe developmental delay (F376 in Rice et al.[1]). There was a marked upregulation of interferon-stimulated gene (ISG) transcripts in blood, a reliable biomarker of *IFIH1*-related disease.[3]

Oral prednisolone was begun at age 16 months, 2 mg/kg for 2 months, followed by weaning over 6 months, and IV immunoglobulin at age 20 months, 1 g/kg monthly for 3 months, with temporary benefits in head and trunk control and decreased irritability and pyrexias. However, these gains were lost on weaning. Given progressive hypertonia and developmental stagnation, 16 months after disease onset he was begun on ruxolitinib 2.5 mg twice daily, increased to 5 mg twice daily 6 weeks later.[4] Over the next 19 months, he regained independent sitting and began using a walker (video, links.lww.com/WNL/A107). Hand function improved so that he could finger feed, pick up and throw objects, use an iPad, and turn taps on and off. He could understand multistep sentences, although his expressive language remained limited to 5–6 words. These clinical observations were reflected in improved functional motor scores (table e-1, links.lww.com/WNL/A109; figure e-1, links.lww.com/WNL/A108; and video). Erythrocyte sedimentation rate and platelet count decreased on treatment, and repeat MRI at age 42 months demonstrated progressive, albeit still mildly delayed, myelination, without atrophy or calcification (figures e-2 and e-3).

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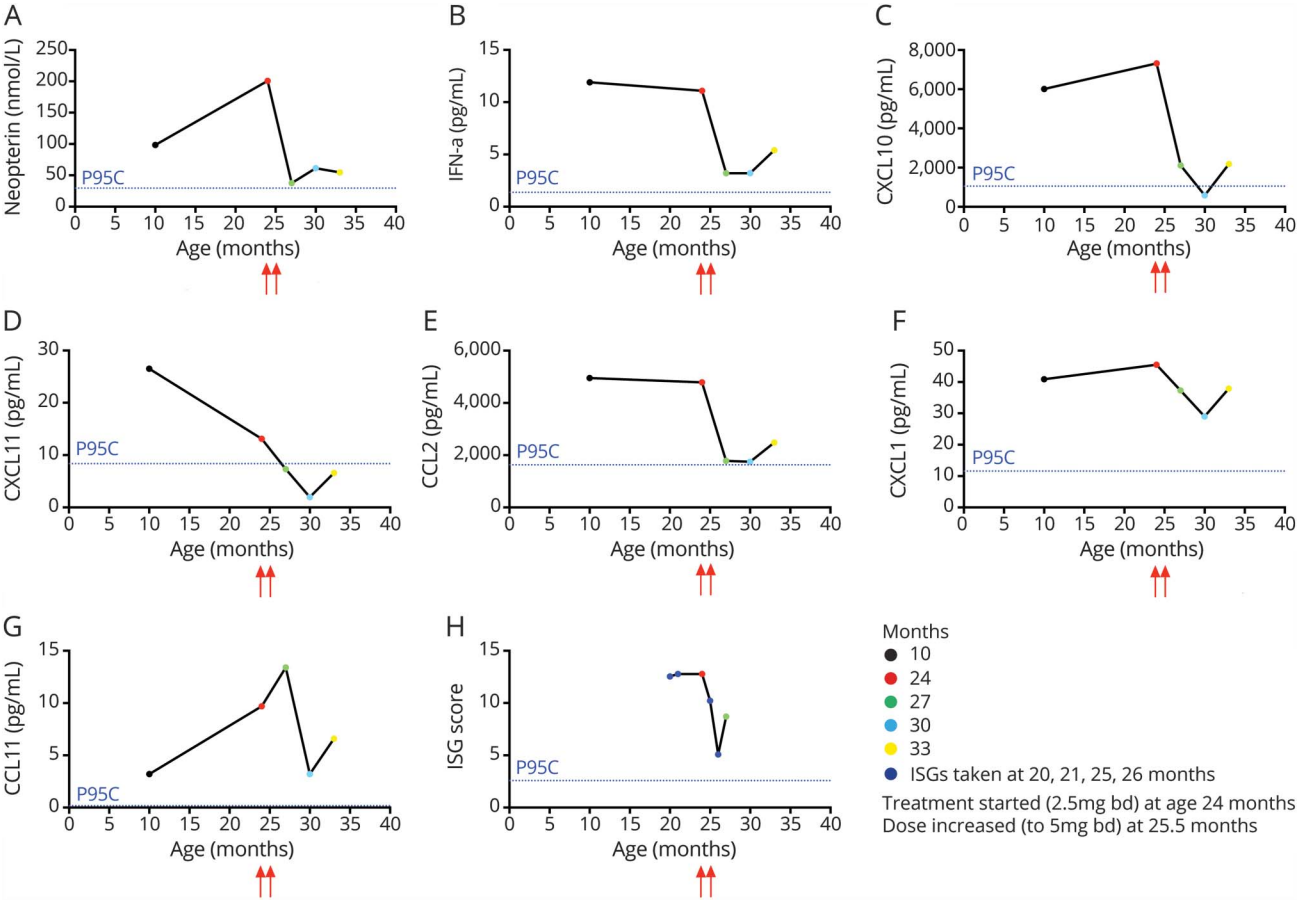
Figure Inflammatory biomarkers during treatment with ruxolitinib



(A) CSF neopterin, (B–G) CSF cytokine/chemokine during treatment with ruxolitinib. Retrospective testing of CSF collected at ages 10 months and 24 months revealed elevated levels of neopterin and cytokines/chemokines (interferon (IFN)–α, CXCL10, CXCL11, CCL2, CXCL1, and CCL11). Serial CSF measures at 3 further time points (27, 30, and 33 months of age) over a 10-month period after initiation of ruxolitinib demonstrated an overall fall in all of these CSF markers. (H) Similarly, serial blood interferon-stimulated gene (ISG) transcript scores were higher before ruxolitinib (at ages 20, 21, and 24 months) than post ruxolitinib (at ages 25, 26, and 27 months). The 95th centile of 20 noninflammatory controls is presented as a dotted line in each panel (P95C).

CSF samples, all acellular, were tested for 32 cytokines and chemokines and compared with 20 noninflammatory pediatric controls.[5] CSF collected before ruxolitinib treatment, at ages 10 and 24 months, demonstrated elevated levels of neopterin, interferon-α, CXCL10, CXCL11, CXCL1, CCL2, and CCL11. Serial measures at 3 time points after treatment initiation (age 27, 30, and 33 months) revealed a fall in these markers, albeit not to normal (figure). Ruxolitinib was measured during treatment, showing a trough concentration of 17.5 and 2.64 ng/mL in serum and CSF, respectively, with a CSF penetrance of 15.1%. Treatment was well-tolerated, with normal 3-monthly full blood counts, renal and liver function, CSF and intraocular pressures, growth, consistently negative JC and BK viral titers, and no side effects.

Discussion

Our patient had an *IFIH1* gain-of-function mutation resulting in interferon-mediated inflammation signaling through the type I interferon receptor and JAK1, as evidenced by an elevation of ISGs in blood and proinflammatory cytokines and chemokines in CSF. Ruxolitinib demonstrates a favorable therapeutic effect in patients with *STING* gain-of-function mutations,[4] suggesting that JAK inhibition might represent a viable approach to blocking type I interferon signaling in the broader monogenic interferonopathy grouping.[6] The efficacy of JAK 1/2 blockade in type I interferon-driven neuroinflammation has not been addressed previously. Although our report involves a single patient, and must be considered in the context of a genotype associated with variability in clinical outcome,[1] we observed substantial developmental gains against a background of previous regression and then developmental stagnation, combined with a positive effect on blood and CSF proinflammatory biomarkers. Ruxolitinib was present in CSF, suggesting access to the CNS. No adverse effects occurred at the doses used. However, immunosuppression is a potential risk, and rebound cytokine storm has been described on withdrawal.[4,7] Given that we describe

a single case (Class IV evidence), this approach requires evaluation in a larger number of patients with sequential developmental and neurologic assessment. JAK inhibition represents a promising approach to the treatment of type I interferon-mediated autoinflammation, possibly including CNS inflammation.

Author contributions

K.K. performed a literature review, CSF cytokine/chemokine testing, and data analysis, and drafted the paper under the supervision of R.C.D. L.W. and S.C. performed CSF cytokine/chemokine testing. S.B. helped with CSF sample storage and the neopterin/ruxolitinib assay. P.B., P.A.B., and A.J. were involved in the clinical management of the case. G.I. R. performed genetic testing, generated interferon stimulated gene data, and was involved in data analysis. Y.J.C. provided expert review of the paper. R.C.D. supervised the project. All authors helped in critical revision of the manuscript and edited the paper.

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Disclosure

K. Kothur, S. Bandodkar, S. Chu, L. Wienholt, A. Johnson, and P. Barclay report no disclosures relevant to the manuscript. P. Brogan has institutional grants from Sobi, Roche, and Novartis and receives consultancy fees from Sobi and Roche. G. Rice, Y. Crow, and R. Dale report no disclosures relevant to the manuscript. Go to Neurology.org/N for full disclosures.

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